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Test of RPA Production Coefficients and Local Assumptions for the Pinyon-Juniper Ecosystem in Central Utah

Warren P. Clary

THE AUTHOR

WARREN P. CLARY is project leader for the Riparian-Stream Ecosystems research work unit at the Intermountain Station's Boise, ID, Forestry Sciences Laboratory. Prior to his current assignment he was project leader for the Ecology and Management of Shrub-Herb Rangelands of the Great Basin research work unit at the Shrub Sciences Laboratory, Provo, UT. He has a B.S. degree in agriculture from the University of Nebraska, an M.S. degree in range management and a Ph.D. degree in plant ecology from Colorado State University.

RESEARCH SUMMARY

The Oak Creek Mountain Range Evaluation Area and other similar evaluation areas were established as part of the Accelerated Range Program of the Forest Service, U.S. Department of Agriculture. One of the purposes was to field test production assumptions, such as those for herbage and shrubs, developed in response to the Resources Planning Act (RPA). Production assumptions from an environmental statement and a soils report were also available for comparison. Four areas of pinyon-juniper removal and forage plant seeding, treated in 1955, 1977, 1978, and 1980 respectively, were studied over a period of 8 years. Although precise positioning of the Oak Creek area within the RPA pinyon-juniper coefficient matrix was difficult, current data and published information support a conclusion that herbage and shrub production assumptions in the RPA scenario and the local soil report were unrealistically high. The estimate provided by the environmental statement for chaining on Utah National Forests was the most accurate.

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Intermountain Research Station
324 25th Street
Ogden, UT 84401

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INTRODUCTION

The 1970 study "The Nation's Range Resources—A Forest-Range Environmental Study" evaluated forests and rangelands in the 48 adjacent United States to determine the current and potential future production of animal unit months (AUM's) of grazing and for associated products and benefits (Forest-Range Task Force 1972). The information was used to construct alternate sets of management goals for range livestock production and to evaluate costs. In response to the study the Chief of the Forest Service, U.S. Department of Agriculture, began the Accelerated Range Program in 1973. This program included a system of large-scale evaluation areas originally conceived to test assumptions of the Forest-Range Task Force and were to be a basis to make appropriate adjustments in the Accelerated Range Program (Sanderson and others 1988). These evaluation areas also were to serve as a basis to test rangeland management production and cost assumptions developed in response to the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA). A secondary purpose was to provide local demonstrations of range improvement practices.

Evaluation areas were established in the Northwest, the South, and in central Utah of the Intermountain Region. The area in Utah, termed the "Oak Creek Mountain Range Evaluation Area," was established in 1978 to provide information on overall effectiveness of range management practices within the pinyon-juniper (*Pinus edulis*, *P. monophylla*, *Juniperus osteosperma*) ecosystem. The project emphasized the necessity of and benefits from coordinated planning and action between Federal, State, and local agencies, as well as private landowners. Despite disruptions caused by two large wildfires, thousands of acres of revegetation work was completed (Pope and Wagstaff 1987).

The basic revegetation effort on the Oak Creek area, excluding fire rehabilitation, was the conversion of specific areas of pinyon-juniper woodland to grass-dominated plant communities to improve forage supplies. The objective of this study was to provide a field test of the specific local and RPA assumptions of herbage and shrub production in the pinyon-juniper ecosystem.

STUDY AREA

The Oak Creek Mountain Range Evaluation Area encompasses 316,000 acres about 15 miles north of Fillmore, UT. The topography is highly variable ranging from desert-shrub flats at the 4,800-foot elevation through rolling foothills and benches to steep rocky peaks that exceed 9,700 feet. The pinyon-juniper zone begins at 5,200 to 5,600 feet elevation with an upper limit of about 8,000 feet on south exposures and up to about 6,000 feet on north exposures. The sagebrush zone is intermingled with the pinyon-juniper zone. Vasey big sagebrush (*Artemisia tridentata* ssp. *vaseyana* is most abundant (Goodrich 1984).

The climate is typical for the Great Basin, with cold, moist winters and warm, dry summers. The average long-term precipitation at the Oak City weather station near the lower edge of the pinyon-juniper zone is 12.06 inches. Average precipitation of most of the pinyon-juniper area included in this study is approximately 13 to 15 inches annually (U.S. Department of Agriculture-U.S. Department of the Interior 1981). Precipitation at the Oak City weather station shows rainfall was 119 to 159 percent of normal in the years of measurement (table 1).

Specific study sites at Oak Creek included new treatments and areas that had been treated in earlier years. Data were obtained from four field situations: Church Hills chaining of 1980, Clay Springs chaining of 1978, Eight-Mile chaining of 1977, and Eight-Mile cabling of 1955. The Church Hills chaining consisted of six study areas of 80 to 200 acres each; three were chained and three were left as untreated controls. Ten transects of 10 plots each were established per area. The plots were circular, 9.6 ft^2 in area, and located 66 feet apart on the transects. Weight estimates were made on the plots for each grass, forb, and shrub species. Two additional plots per transect were estimated then clipped, ovendried, and weighed to determine correction factors for conversion to dry weight. Twelve transects were located in the Clay Springs chaining before treatment with the intent that three would be in untreated areas. However, after the planned treatment and an unplanned wildfire, one transect could not be relocated and no transect remained

Table 1—Precipitation at Oak City for those years when tree removal and seeding or vegetation sampling occurred

Month	Year										
	1955	1956	1977	1978	1979	1980	1981	1982	1983	1984	1985
January	1.55	2.47	0.86	2.60	1.43	2.23	0.72	1.27	0.82	0.78	0.90
February	2.16	.92	.12	2.00	1.42	2.62	.22	.29	1.64	1.05	1.03
March	0.15	.06	1.09	2.74	2.03	3.39	1.60	1.62	2.82	2.54	1.47
April	.30	.86	.24	2.51	.93	.65	2.20	.74	2.45	1.82	.78
May	.99	.82	1.54	1.62	1.51	3.20	2.85	1.44	1.47	.54	1.88
June	1.48	.28	.35	.08	.91	.00	.30	.36	.58	2.54	1.71
July	.74	.61	1.16	.09	.10	.47	.20	.78	.33	2.44	.84
August	.77	.51	.84	.91	.76	.32	.49	1.33	2.08	1.58	.00
September	.75	.04	.59	2.43	.00	1.83	1.96	5.01	1.48	1.17	1.27
October	.28	1.00	.73	.27	1.44	1.63	4.07	2.31	1.02	2.56	1.31
November	.82	.05	.30	2.90	1.31	1.33	1.23	.93	3.10	1.09	1.84
December	.56	.13	.76	1.01	.43	.32	.95	2.18	2.44	1.26	1.35
Calendar year	10.55	7.75	8.58	19.16	12.27	17.99	16.79	18.26	20.23	19.37	14.38
Crop year [1]	—	7.82	5.42	13.93	14.84	15.27	13.00	13.93	20.21	17.31	13.85
Yield index[2]	—	72	42	145	156	161	133	145	221	186	144

[1] Crop year = September to June (Sneva and Britton 1983).
[2] Yield index = expected plant production level compared to a crop year with median precipitation (Sneva and Britton 1983).

Table 2— Years of sampling on the four Oak Creek study sites

Site	Year				
	1978	1980	1981	1982	1985
Church Hills					
Treated				X	X
Untreated (or control)		X		X	X
Clay Springs					
Treated		X			X
Untreated (or control)	X				
Eight-Mile 1977					
Treated		X		X	X
Untreated (or control)					
Eight-Mile 1955					
Treated		X	X		X
Untreated (or control)					

with an intact overstory. The Eight-Mile study sites were established in two areas previously cleared of trees and seeded to herbaceous species—one in 1955 and one in 1977. Twenty sample locations were equally distributed among swale bottom, side slope, and ridge crest topography on a generally south aspect to study forage production potential of the three slope positions. Each sample location consisted of two transects of 10 plots each.

Although measurement of plant production was conducted in 3 years on each of the study areas, the sampling was spread over an 8-year period due to timing of seeding, grazing rotations, and so forth (table 2). Sampling was conducted only when individual areas were in a rested or deferred grazing situation. The areas were treated in different years (were of different ages), and data were collected in different sets of years. Although differences in planting technique, weather, and site contribute to variation in the field data, the results provide a basis for interpretation of trends.

PRODUCTION ASSUMPTIONS

Production assumptions were garnered from one national source—the RPA management scenario—and local sources—National Forests' environmental statement and a soil survey.

National RPA Assumptions

The RPA management scenario prepared for the pinyon-juniper ecosystem described four productivity classes subdivided by condition class and range management strategy (table 3). A copy of RPA management scenarios and assumptions is on file at the Forestry Sciences Laboratory, Boise, ID. The management strategy of the Oak Creek area was similar to strategy D of the scenario. This consisted of intensive management to increase livestock forage consistent with constraints of maintaining the environment and providing for multiple use. Practices such as pinyon-juniper removal and seeding with forage species were a part of this strategy, as were the installation of fencing and water developments to obtain a more uniform distribution of livestock.

No definition or description of the condition classes was provided in the scenerio. Desirable perennial forage plants on the study sites before treatment made up only 13 to 40 percent of the herbage and shrub production, and the density of the tree stand limited the herbage and shrub understory production to about 100 lb per acre.

Assumptions for National Forests

In the chaining environmental statement, the assumption for change in herbage ("forage") production was an increase of 500 to 700 lb per acre "under favorable conditions" on National Forests in Utah after removal of pinyon-juniper stands (USDA 1973).

Table 3—RPA assumptions for herbage and shrub productivity for the D level management strategy

Productivity class	Condition class	Pounds per acre per year
1 High	1 Good	1,200
	2 Fair	1,100
	3 Poor	1,000
	4 Very poor	800
2 Mod. high	1	1,000
	2	900
	3	800
	4	700
3 Med. low	1	700
	2	600
	3	500
	4	400
4 Low	1	300
	2	200
	3	100
	4	100

Assumptions Based on a Soil Survey

A contract soil survey report prepared for the Forest Service provided estimates of potential vegetation productivity (Stoneman and others 1979). The production of air-dry vegetation in pounds per acre was estimated for both unfavorable (less than average precipitation) and favorable (greater than average precipitation) years. The soils of three study areas had similar estimated herbage and shrub productivity—660 lb per acre in unfavorable years and 1,415 lb per acre in favorable years. The estimates for the Clay Springs area were less—460 and 780 lb/acre—apparently because of the sandy eolian soils that were poorly developed and excessively drained.

VEGETATION TREATMENT

The three most recent vegetation treatments were similar in that the trees were removed by pulling an anchor chain between two crawler tractors and the areas were seeded from the air. The areas were chained a second time to cover the seed and to improve the effectiveness of tree removal.

The seed mixture for the Church Hills chaining was:

Crested wheatgrass (*Agropyron cristatum* and *A. desertorum*)	2.0 lb per acre
Intermediate wheatgrass (*A. intermedium*)	0.6
Pubescent wheatgrass (*A. trichophorum*)	0.6
Russian wildrye (*Elymus junceus*)	1.2
Hard sheep fescue (*Festuca ovina* ssp. *duriuscula*)	0.2
Ladak alfalfa (*Medicago sativa* var. *ladak*)	1.2
Yellow sweetclover (*Melilotus officinalis*)	0.2
Small burnet (*Sanguisorba minor*)	2.0
Total	8.0 lb per acre

A small amount of bitterbrush (*Purshia tridentata*), cliffrose (*Cowania mexicana*), and fourwing saltbush (*Atriplex canescens*) seed was also applied by dribblers on the crawler tractors during the second chaining.

The seed mixture for the Clay Springs chaining was:

Crested wheatgrass	2.6 lb per acre
Intermediate wheatgrass	4.0
Pubescent wheatgrass	1.5
Russian wildrye	0.8
Smooth brome (*Bromus inermis*)	2.9
Indian ricegrass (*Oryzopsis hymenoides*)	0.1
Total	11.9 lb per acre

Some browse seed was also applied by a dribbler on one of the tractors.

The 1977 treatment portion of the Eight-Mile area was seeded with:

Crested wheatgrass	2.5 lb per acre
Intermediate wheatgrass	6.3
Pubescent wheatgrass	1.2
Ladak alfalfa	0.5
Total	10.5 lb per acre

In addition, about 0.2 lb per acre of bitterbrush seed was applied by dribbler.

The oldest treatment area (1955) was cabled twice, and the slash was bunched into windrows with a small crawler tractor. Wheatgrasses were seeded on the area, but the sequence of procedures and detail of seed mixtures are not known.

RESULTS

Data were collected from all treatment areas the final year of study (1985). Table 4 presents these data by species to illustrate composition of the plant communities at the end of the study. The older treatment sites (Eight-Mile area) were strongly dominated by introduced wheatgrasses. They made up 91 percent of the composition in the 1955 treatment area and 71 percent in the 1977 treatment area. Intermediate and pubescent wheatgrasses were most prevalent followed by crested wheatgrass. These grasses so dominated the site that only a limited amount of shrubs were present and there were few forbs. The Clay Springs and Church Hills areas, which were treated as part of the Oak Creek Mountain Range management program, had less dominance by seeded grasses—60 and 44 percent, respectively. Western wheatgrass (*Agropyron smithii*), bluebunch wheatgrass (*A. spicatum*), and Indian ricegrass—desirable native perennial grasses—were more apparent in the composition. A greater variety of both forbs and shrubs were also present in the areas more recently treated.

Table 4—Data (lb per acre) collected in 1985 from the four pinyon-juniper treatment areas

	Eight-Mile 1955 treatment			Eight-Mile 1977 treatment					
	Slope position			Slope position					
	Swale Bottom	Side Slope	Ridge Crest	Swale Bottom	Side Slope	Ridge Crest	Clay Springs	Church Hills Treated	Church Hills Untreated
Grasses									
Agropyron cristatum	60.7	175.0	123.5	274.8	167.0	291.3	153.1	123.1	0.3
Agropyron intermedium	389.7	247.3	193.3	416.5	373.7	153.0	42.1	88.1	.0
Agropyron smithii	24.0	.0	.0	7.8	.0	.0	12.2	11.1	2.2
Agropyron spicatum	.0	6.0	27.3	5.8	51.3	95.3	70.8	98.9	21.6
Agropyron trichophorum	363.0	197.7	140.0	155.5	51.3	34.3	46.2	26.0	.3
Bromus inermis	.0	.0	.0	.3	3.0	1.3	43.0	1.4	.0
Bromus tectorum	.3	.3	.8	.3	8.0	5.3	53.0	9.1	18.1
Dactylis glomerata	.0	.0	.0	.0	.0	.0	.0	1.7	.0
Elymus junecus	.0	.0	.0	.0	.0	.0	.0	2.0	.0
Oryzopsis hymenoides	.0	.0	.0	.0	.0	.0	8.9	13.2	4.0
Poa bulbosa	2.7	2.3	1.8	40.0	.0	1.7	.0	.0	.0
Poa fendleriana	.0	.0	.0	.0	.0	.0	.0	.0	.1
Poa secunda	8.0	6.7	3.5	8.0	24.3	7.7	9.7	3.2	17.8
Sitanion hystrix	.0	.0	.0	.1	.3	1.0	1.1	5.3	3.6
Stipa comata	.0	.0	.0	.0	.0	3.0	.0	1.7	.5
Forbs									
Agoseris glauca	.0	.0	.0	.0	.0	1.0	.0	.3	T
Allium acuminatum	.0	.0	.0	.0	.0	T	.0	T	.2
Alyssum desertorum	.0	.0	.0	.0	.0	.1	.0	T	.3
Antennaria dimorpha	.0	.0	.0	.0	T	.4	.0	.1	.1
Arabis holboelii	.0	.3	.0	.0	.0	.0	.0	.2	T
Arenaria kingii	.0	.0	.0	.0	.0	.0	.0	.1	T
Astragalus cibarius	.0	.0	.0	.3	.1	.0	.0	.0	.0
Astragalus convallarius	.0	.0	1.8	.0	.0	.0	.0	2.0	1.6
Astragalus eurekensis	.0	.0	.0	.0	.0	.0	.0	.2	.7
Astragalus utahensis	.0	.0	.0	.0	.1	.0	.0	.0	.0
Calochortus nuttallii	.0	.0	.0	.1	.3	2.3	.0	.3	.7

(con.)

Table 4 (Con.)

	Eight-Mile 1955 treatment			Eight-Mile 1977 treatment					
	Slope position			Slope position					
	Swale Bottom	Side Slope	Ridge Crest	Swale Bottom	Side Slope	Ridge Crest	Clay Springs	Church Hills Treated	Church Hills Untreated
Camelina microcarpa	.0	.0	.0	T	.0	.0	.0	.1	.2
Castilleja chromosa	.0	.0	.0	.0	.0	.3	.0	.1	.0
Chaenactis douglasii	.0	.0	.0	.0	T	.7	.0	4.7	4.0
Collinsia parviflora	.0	.0	.0	T	.3	T	.0	.2	.4
Comandra pallida	.0	.0	.0	.0	.0	.0	.0	2.7	.0
Cryptantha humilis	.0	.0	.0	.1	.0	.7	.1	.1	1.6
Descurainia pinnata	.0	T	.0	.0	.8	T	T	1.2	.1
Draba cuneifolia	.0	.0	T	T	T	T	T	.1	.2
Epilobium paniculatum	.0	.0	.0	.0	.3	.0	.0	T	T
Erigeron pumilus	.0	.0	.0	.0	.0	.0	.0	.1	T
Eriogonum cernuum	.0	.0	.0	.0	.0	.0	.1	T	T
Eriogonum ovalifolium	.0	.0	.0	.0	.7	.0	.0	.0	.0
Eriogonum racemosum	.0	.0	.0	.0	.7	.0	.3	.0	.0
Eriogonum umbellatum	.0	.0	.0	.0	.3	.0	.0	6.3	2.3
Erodium cicutarium	.0	.0	.0	.0	.0	.1	T	.0	.0
Gayophytum spp.	.0	.0	.0	.0	.1	.1	.0	.1	.0
Gilia aggregata	.0	.0	.0	.0	.0	.0	.0	.1	T
Gilia inconspicua	.0	.0	.0	.0	T	.7	.0	.1	.2
Lactuca serriola	.0	.0	.0	.3	5.0	.7	3.2	15.0	4.5
Linum lewisii	.0	.0	.0	.0	.0	4.7	.0	.8	.0
Lithospermum incisum	.0	.0	.0	.0	.0	.0	.0	.3	.2
Lomatium grayii	.0	.0	.5	.0	1.3	.0	.0	.0	.1
Machaeranthera canescens	.0	.0	.0	.0	.0	.0	.1	.4	.2
Medicago sativa	.0	.0	.0	47.3	60.7	.0	T	9.1	.0
Microsteris gracilis	T	T	.1	T	.3	.2	T	.4	.3
Penstemon humilus	.0	.0	.0	1.0	.1	.0	.0	2.8	1.4
Petradoria pumila	.0	.0	.0	.0	2.3	5.7	.0	7.0	1.6
Phlox hoodii	.0	.0	11.0	.0	.0	.0	.0	.1	.4
Phlox longifolia	.0	.0	.0	.0	.0	.0	.0	T	.6
Physaria chambersii	.0	.0	.1	.0	.8	.0	.0	.1	.6
Psoralea lanceolata	.0	.0	.0	.0	.0	.0	.5	.0	.0
Ranunculus testiculatus	T	T	T	T	T	T	T	.1	.8
Salsola kali	.0	.0	.0	.0	.0	.0	.0	.2	.0
Sanguisorba minor	.0	.0	.0	.0	.0	T	.0	20.3	.0
Sisymbrium altissimum	.0	.0	.0	.0	.0	.0	13.2	T	.0
Sphaeralcea coccinea	.0	.0	.0	.0	T	.0	.0	.4	.7
Sphaeralcea grossulariaefolia	.0	.0	.0	.0	.0	.0	.1	.8	.0
Streptanthus cordatus	.0	.0	T	.0	1.3	.1	.0	1.3	.2
Tragopogon dubius	.0	T	.0	.3	1.0	.5	.0	9.5	1.5
Vicia americana	.3	.0	T	2.0	.7	.1	.0	.7	2.9
Shrubs									
Artemisia nova	.0	.0	.0	.0	.0	.0	.0	8.8	1.0
Artemisia tridentata	4.0	.3	4.0	104.8	106.7	24.0	11.3	23.5	28.1
Chrysothamnus viscidiflorus	.0	T	27.3	9.0	.0	29.3	.1	3.4	.6
Cowania mexicana stransburiana	.0	.0	.0	.0	16.7	1.0	.0	1.4	.4
Eriogonum microthecum	.0	.0	.0	.0	.0	.0	.0	1.4	.2
Leptodactylon pungens	.0	.0	1.3	.0	.0	1.0	.0	3.3	1.2
Purshia tridentata	.0	.0	.0	1.5	4.3	.7	3.4	4.9	6.9
Tetradymia canescens	.0	.0	.0	.0	.0	.0	.0	.7	.0
Xanthocephalum sarothrae	.5	6.3	19.0	34.3	8.7	15.7	3.1	28.5	25.7

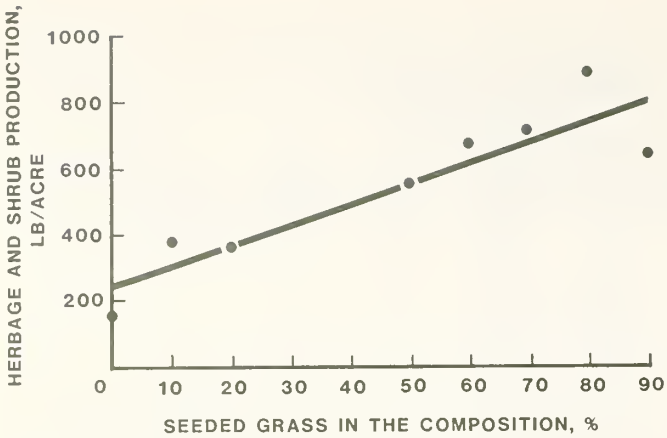

Figure 1—Relationship of percent seeded grassses and total production.

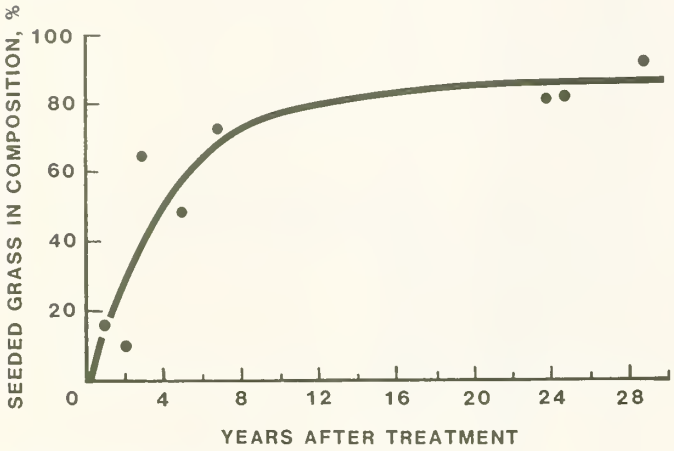

Figure 2—Percent seeded grasses and year after treatment.

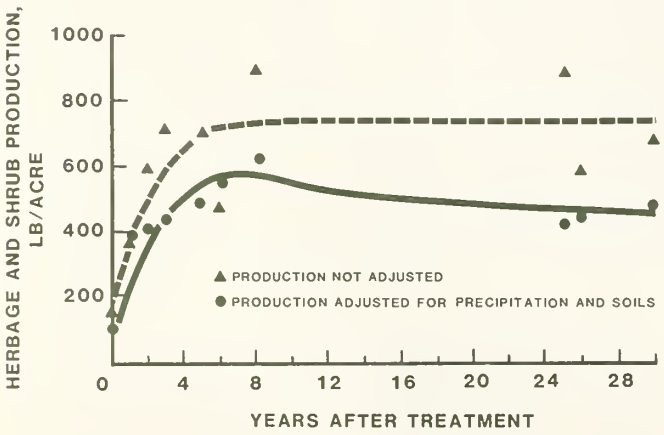

Figure 3—Production time trend.

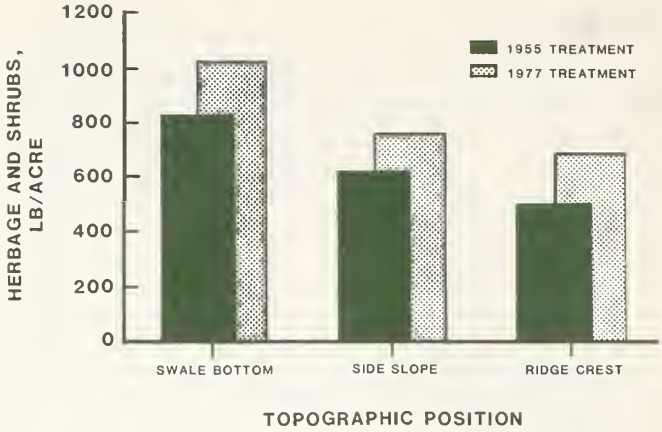

Figure 4—Effect of topography on herbage and shrub production. Bars represent a mean for 3 years of data.

Total production was closely correlated to the proportion of the seeded wheatgrasses (fig. 1). This suggests that many of the other plants present following tree removal, both natives and exotics, are inefficient in the use of the existing site productivity, or at least they are slow in developing the densities necessary to fully utilize the site. The older stands tended to be dominated by intermediate and pubescent wheatgrasses that are rhizomatous and sod-formers (Asay and Knowles 1985; Wasser 1982). These seeded grasses have the capability to increase stand densities over time by vegetative means. The data from Oak Creek suggest that about 8 to 10 years are required for these grasses to reach a stable proportion of the composition, which may be over 80 percent (fig. 2). Similar to this trend, the total production of herbage and shrubs appeared to increase for as much as 8 years (fig. 3). Previous results from the Utah area have demonstrated that the level of total herbage production in the early years after seeding is strongly affected by the proportion of seeded grass in the plant community (Clary and Wagstaff 1987; Phillips 1977).

There was a substantial difference among swale bottom, side slope, and ridge crest areas of topography (fig. 4, tables 5 and 6). Herbage and shrub production in the swale bottom portions of the topography with its deeper soil and more favorable soil moisture condition was a third and two-thirds greater than the side slope and ridge crest portions of the area, respectively.

Comparison With Assumptions

The RPA assumptions for herbage and shrub production under intensive management vary from 1,200 down to 100 lb per acre depending upon productivity class and condition class (table 3). The older treatment areas, considered to represent the long-term production potential for seeded stands, have a strong dominance of seeded grasses and therefore were considered in "good" condition. These areas (tables 5 and 6) averaged 740 lb per acre of herbage and shrub production with a 95 percent

Table 5—Herbage and shrub production by slope position on the 1955 Eight-Mile treatment area

Vegetation	1980 Swale Bottom	1980 Side Slope	1980 Ridge Crest	1981 Swale Bottom	1981 Side Slope	1981 Ridge Crest	1985 Swale Bottom	1985 Side Slope	1985 Ridge Crest
Grasses									
Perennial									
Seeded	[1]836 ± 77	592 ± 57	285 ± 52	662 ± 47	444 ± 24	340 ± 65	813 ± 149	620 ± 115	457 ± 89
Native	35 ± 9	61 ± 21	53 ± 19	50 ± 50	56 ± 27	24 ± 13	32 ± 22	13 ± 10	31 ± 30
Annual	11 ± 4	33 ± 26	31 ± 22	15 ± 15	1 ± 1	2 ± 2	2 ± 1	3 ± 2	3 ± 1
Forbs	13 ± 9	3 ± 1	13 ± 5	9 ± 5	1 ± 1	34 ± 26	0 ± 0	0 ± 0	13 ± 12
Shrubs	7 ± 3	12 ± 7	77 ± 24	7 ± 4	21 ± 11	94 ± 20	5 ± 4	7 ± 3	52 ± 27
Total	902 ± 74	701 ± 43	459 ± 32	743 ± 25	523 ± 24	494 ± 48	852 ± 168	643 ± 113	556 ± 31
Median[2] year estimate	560	435	285	559	393	371	592	446	385

[1]Pounds per acre $\bar{x} \pm s.e.$
[2]Estimated herbage and shrub production under conditions of median September to June precipitation (Sneva and Britton 1983).

Table 6—Herbage and shrub production by slope position on the 1977 Eight-Mile treatment area

Vegetation	1980 Swale Bottom	1980 Side Slope	1980 Ridge Crest	1982 Swale Bottom	1982 Side Slope	1982 Ridge Crest	1985 Swale Bottom	1985 Side Slope	1985 Ridge Crest
Grasses									
Perennial									
Seeded	[1]747 ± 106	376 ± 83	307 ± 79	636 ± 68	379 ± 86	321 ± 58	847 ± 118	595 ± 83	480 ± 135
Native	66 ± 20	157 ± 36	144 ± 47	48 ± 14	119 ± 34	164 ± 65	22 ± 6	76 ± 53	107 ± 66
Annual	62 ± 8	33 ± 8	54 ± 12	129 ± 23	114 ± 39	203 ± 26	40 ± 40	8 ± 8	7 ± 4
Forbs	16 ± 7	15 ± 3	14 ± 4	41 ± 20	42 ± 27	17 ± 4	51 ± 28	77 ± 38	20 ± 15
Shrubs	54 ± 18	40 ± 16	37 ± 12	160 ± 47	103 ± 40	108 ± 34	150 ± 61	136 ± 72	72 ± 38
Total	945 ± 89	621 ± 48	556 ± 33	1,014 ± 42	757 ± 65	813 ± 66	1,110 ± 109	892 ± 71	686 ± 105
Median[2] year estimate	588	386	346	699	523	560	770	620	476

[1]Pounds per acre $\bar{x} \pm s.e.$
[2]Estimated herbage and shrub production under conditions of median September to June precipitation (Sneva and Britton 1983).

confidence limit of 680 to 800 lb per acre. The more recent seedings, for purposes of this evaluation, were considered in "fair" condition within the RPA matrix because of less dominance of seeded species. These sites produced approximately 530 lb per acre (tables 7 and 8) with a confidence limit of 490 to 570 lb per acre. The herbage and shrub production appeared, therefore, to average about 110 to 220 lb per acre less than expected for a site of average productivity, about 260 to 370 lb per acre less than expected for a site of moderately high productivity, and 460 to 570 lb per acre less than expected for a site of high productivity (table 9).

Precipitation in the Oak Creek area was above average from the late 1970's to the last year of production measurements, 1985. At Oak City, precipitation averaged 140 percent of normal during the years the older seedings were sampled (used as a basis for long-term productivity estimates). Because average precipitation for the study area was estimated to be 13 to 15 inches per year (U.S. Department of Agriculture-U.S. Department of the Interior 1981), a 40 percent increase during measurement years would have resulted in precipitation averaging approximately 20 inches. This is near the upper end of the range of average precipitation—8 to 22 inches—for the pinyon-juniper ecosystem (Clary 1987). Soil depths of 11 to 20 inches (Stoneman and others 1979; and RPA scenario) also suggest the Oak Creek area should be above average in plant production potential for the pinyon-juniper ecosystem. If we assume that during these years the study areas should have exhibited "moderately high" productivity (1,000 lb per acre under good condition), the general production levels are approximately one productivity class lower than suggested by the RPA assessment. Only the "swale bottom" topographic position (measured in the older seedings) had sufficient production (average of 928 lb per acre from tables 5 and 6) to approach expectations from the RPA matrix. In addition, the swale bottoms are actually more representative of big sagebrush site inclusions than pinyon-juniper sites, as such.

Table 7—Herbage and shrub production before (1978) and after (1980, 1985) treatment at Clay Springs

Vegetation	Year 1978	1980	1985
Grasses			
Perennial			
Seeded	[1]0 ± 0	55 ± 16	284 ± 69
Native	6 ± 2	89 ± 39	103 ± 53
Annual	12 ± 3	114 ± 17	53 ± 23
Forbs	9 ± 2	33 ± 2	18 ± 5
Shrubs	27 ± 12	67 ± 26	18 ± 8
Total	54 ± 15	358 ± 58	476 ± 76
Median[2] year estimate	37	222	331
Median year estimate adjusted to account for less productive soils[3]	62	370	552

[1] Pounds per acre $\bar{x}$±s.e.
[2]Estimated herbage and shrub production under conditions of median September to June precipitation (Sneva and Britton 1983).
[3]The Clay Springs soils were estimated to be 60 percent as productive as the remainder of the study area (Stoneman and others 1979).

Table 8—Herbage and shrub production for treated and control areas during pretreatment (1980) and posttreatment periods (1982, 1985) at Church Hills

Vegetation	1980 Chained	1980 Control	1982 Chained	1982 Control	1985 Chained	1985 Control
Grasses						
Perennial						
Seeded	[1]0 ± 0	0 ± 0	51 ± 10	0 ± 0	243 ± 25	1 ± 0
Native	42 ± 2	26 ± 2	122 ± 10	31 ± 4	133 ± 14	50 ± 5
Annual	21 ± 2	16 ± 2	173 ± 13	92 ± 10	9 ± 3	18 ± 4
Forbs	52 ± 3	40 ± 3	85 ± 12	14 ± 4	90 ± 10	31 ± 4
Shrubs	41 ± 4	51 ± 8	159 ± 19	113 ± 15	76 ± 13	64 ± 11
Total	156 ± 8	133 ± 12	590 ± 28	250 ± 18	551 ± 27	164 ± 18
Median[2] year estimate	98	83	408	174	383	114

[1]Pounds per acre, $\bar{x}$±s.e.
[2]Estimated herbage and shrub production under conditions of median September to June precipitation (Sneva and Britton 1983).

The assumptions from a more local viewpoint, developed in a Forest Service environmental statement on chaining of National Forest System lands in Utah (USDA FS 1973), project that an *increase* of 500 to 700 lb per acre due to chaining and seeding could be expected "under favorable conditions." If the average pretreatment production of 106 lb per acre is added to the assumed increase, the environmental statement projection is close (within 66 to 76 lb per acre) to the actual measured production (table 9). Production in the swale bottom topographic position exceeded the environmental statement assumption by 228 to 428 lb per acre.

The productivity assumptions made in the soil report (Stoneman and others 1979) were the furthest from reality. The estimates were about double the average measured production and even exceeded the production of the swale bottom topographic position of the older seedings by a substantial margin (~487 lb per acre) (tables 5, 6, and 9).

Another evaluation approach used was to approximate the production to be expected under normal precipitation. The production levels of the four study areas were adjusted to a median-precipitation-year basis by the methodology of Sneva and Britton (1983) (tables 5 to 8).

Table 9—Difference between assumptions and actual or adjusted data (pounds/acre)

Range	Actual production	RPA		Environmental statement		Soil report	
		Assumption	Difference from Actual	Assumption	Difference from Actual	Assumption	Difference from Actual
Good condition ranges							
High production	740	1,200	460	—	—	—	—
Moderately high production	740	1,000	260	[1]806	66	[2]1,415	675
Average production	740	850	110	—	—		
Moderately low production	740	700	(–)40	—	—	[2]780	40
Fair condition ranges							
High production	530	1,100	570	—	—		
Moderately high production	530	900	370	[1]606	76	—	—
Average production	530	750	220	—	—	—	—
Moderately low production	530	600	70	—	—	—	—
Data adjusted to represent good range condition and average soil and precipitation conditions	500	850	350	—	—	[3]1,038	538

[1]Estimate was 500–700-lb/acre increase under "favorable" conditions which suggests average or above average precipitation. Pretreatment production was 106 lb/acre at Oak Creek.

[2]The 1,415-lb per acre estimate represents a typical estimate of production for the Oak Creek area in favorable years, and the 780 lb/acre represents an estimate of production for below-average soils in the Oak Creek area in favorable years (Stoneman and others 1978).

[3]Average for estimates of favorable and unfavorable years for typical soil conditions.

In addition, the production data from Clay Springs were further adjusted to account for less productive eolian soils to place these values on a par with the other three study areas (table 7). The adjusted production data were assumed to more accurately represent changes over time under conditions of average precipitation and average soil conditions. The data suggest a peaking of production 6 to 8 years after seeding at about 550 lb per acre and a gradual decline to approximately 450 lb per acre in older seedings (fig. 3). Using 500 lb as the best estimate of average long-term production potential, the study areas at Oak Creek still appeared to be at least one productivity class less than assumed in the RPA scenario for an "average" pinyon-juniper site (table 9). The adjusted average value for the swale bottom topographic position (628 lb per acre) also fell short of the "average" expected production (850 lb per acre).

DISCUSSION

The reasons plant production did not meet assumed production levels are not known. A major problem occurs in fitting a specific area into a nonspecific array. Without clear identifiers the proper location within an array, such as that in table 3, may involve a bit of guesswork. Some elements of the environment such as precipitation and soils provide clues, but no specific guides are available. When a viable classification of the pinyon-juniper type is developed, the proper positioning of a particular area within such an array will be more likely. The best approach to evaluate or test an array of production coefficients for a wide-ranging vegetation zone would be to draw unbiased samples from across the vegetation zone and determine the statistical distribution of measured outputs. This would alleviate the need to identify the exact "pigeon-hole" into which an individual location fits.

A second question is whether the production levels were assumed to represent grazed or nongrazed situations. A review of recent literature suggests that, after tree removal, *grazed* pinyon-juniper areas rarely exceed 800 lb per acre except in localized situations. Conversely, after tree removal *ungrazed* pinyon-juniper areas often exceed 1,200 lb per acre (Clary 1987). Presumably, the grazed situation should apply to the RPA assumptions because the key issue was a question of AUM's of grazing capacity. However, this problem was not recognized in the RPA scenario nor in the local assumptions.

Another possible problem concerns the production trends of seeded stands. Stands of good initial density, which are often established when drilling or other intensive revegetation techniques are used, typically peak in production after 2 to 3 years (White 1985). These stands then decline through at least the sixth year to about 50 percent of their peak value (fig. 5). If production sampling occurs during the peak production period, the values obtained are highly biased estimates of long-term average production. A different pattern occurs when the seeded stand is sparse or when no seeding is done and the native vegetation is allowed to recover naturally. A thickening of the stand and an increase in production may occur for some years, particularly if sodformers are part of the composition. In their Southwestern study, Arnold and others (1964) found approximately 10 years were required to achieve maximum production of herbage after juniper removal (fig. 6). A similar pattern undoubtedly occurs in

Figure 5—Effects of stand age on herbage yield in the Northern Great Plains per inch of April through June precipitation (after White 1985).

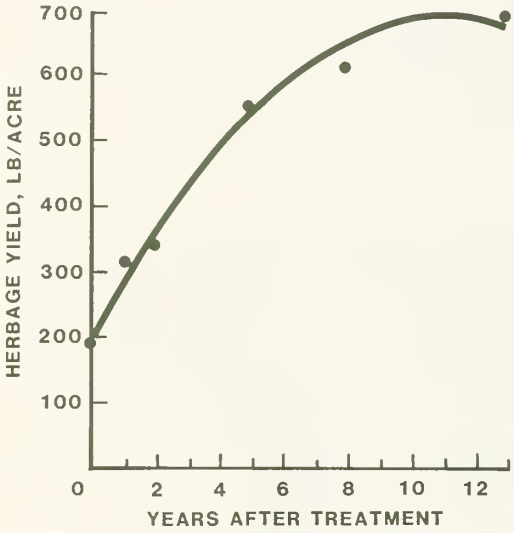

Figure 6—Herbage yields by number of growing seasons after control of juniper and pinyon (after Arnold and others 1964).

many Intermountain chaining and seeding efforts wherein the initial stands are often thin in comparison to stands obtained by more intensive seeding techniques. In such instances, a continued thickening of the stand often results in continued gain in production for several years because the total rooting zone was not initially occupied. Depending upon initial conditions and plant composition, we might expect a difference of up to 8 years among stands as to when their peak production is achieved.

In other reported pinyon-juniper treatments from Utah, 717 lb per acre were produced 7 years after a cabling and seeding treatment in a precipitation year that should have produced yields 132 percent of normal (Christensen and others 1966). Thus, yields to be expected in a median precipitation year (Sneva and Britton 1983) were approximately 543 lb per acre. About 700 lb of total herbage increase per acre was produced 5 years after chaining in 59 projects in southern Utah (Phillips 1977). Many of these projects could have been near peak production if they followed the trend illustrated in figure 3. The data of Payne and Busby (1980) showed an average of only 379 lb per acre of grasses with few forbs were produced on 18 chainings 6 to 25 years old on National Forests in Utah. Although production of shrubs was not determined, the rate of grass production was about the same as occurred on the most recent treatment areas at Oak Creek—Church Hills and Clay Springs (~350 to 400 lb per acre). The average annual precipitation for these sites was approximately 14 inches or about the estimated long-term mean for the study areas at Oak Creek.

CONCLUSIONS

Direct comparisons of different treatment areas are difficult because many important factors such as weather, soils, grazing history, and plant composition are often not recorded. However, general patterns in the data provide some guidance. Results from the Oak Creek Mountain Range Evaluation Area, examined from several viewpoints, and other published results support a conclusion that RPA assumptions and soil report estimates of herbage and shrub production potential were overly optimistic for average long-term grazed conditions in central Utah pinyon-juniper. The swale bottom topographic position was the only situation with sufficient productivity to approach expectations of the RPA coefficient matrix. The estimate of overall forage production provided by the Forest Service environmental statement was the most accurate.

Factors that cause difficulties in making accurate site predictions from assessment matrices include: (1) few guides for positioning a specific site within the assessment matrix; (2) lack of information on grazed or ungrazed situation of original data sources; and (3) lack of information concerning the age and original seeding success of seeded stands.

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RPA production assumptions, an environmental statement, and a soils report are available as bases for management planning. To test these assumptions a study was developed using four different-aged areas of pinyon-juniper removal and forage plant seeding. Data were collected over an 8-year period to provide ground data against which to test assumptions.

KEYWORDS: evaluation area, chaining, seeding, topographic position

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